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Determining and Mapping the Probability of Aquatic Plant Colonization

by Jerrell R. Ballard, Jr.

The ability of a water body (reservoir, stream, estuary) to establish and colonize native or noxious aquatic plant species depends on many physical and chemical factors. These factors have been studied within the Corps of Engineers Aquatic Plant Control Research Program (APCRP) and the aquatic plant management community for many years. One important focus has been on characterizing the conditions under which plants will colonize and grow. Often a manager wishes to determine the impact of various management strategies on the plant distribution pattern within the whole project area. This requires a procedure that captures and integrates the results of greenhouse, laboratory, and field experiments (conducted under specific, controlled conditions). The procedure must be useful for all candidate sites such as streams, reservoirs, or other navigable waters. In addition, to be consistent with other cost-benefit analyses and risk-based assessments, managers and planners need information on "potential areas" of plant colonization in terms of probabilities.

Aquatic plant colonization is indeed a function of various biophysical, spatial, and human factors. From knowledge of these fundamental relationships, colonization can be modeled as a series of conditions or events and the independent likelihood of each can be calculated.

To express plant colonization in terms of the probability that it will occur requires a conceptual model of the events. Colonizing aquatic plants at any particular site or location can be modeled with two primary events:

- The introduction of viable plant material to the waterbody at a particular site or location.
- The successful establishment of that plant material at the location.

Each of these events is influenced by numerous factors such as light availability, substrate condition, proximity to source of introduction, and fragment dispersal. The relationships between these factors and the two events are depicted in Figure 1.

To effectively apply and demonstrate the conceptual colonization methodology, a site in the Upper Mississippi River, Pool 4, was selected. This area has several ongoing R&D efforts by the Waterways Experiment Station and contained adequate geospatial and environmental data for demonstration. Important data types for Pool 4 were bathymetry, turbidity, substrate types, and waterflow. An example of the bathymetry data for Pool 4 is shown in Figure 2. Depth is depicted as shades of gray (lighter shades indicate shallow depths and dark shades represent deeper depths).

Probability of introduction of viable plant material

The dispersal of aquatic plants is highly dependent upon current/flow, water depth, and distance of travel from the point of introduction. The spatial variable is shown in Figure 3. (In this figure and the following figures, lighter shades of gray represent regions with low probabilities and darker shades represent areas of high probabilities).

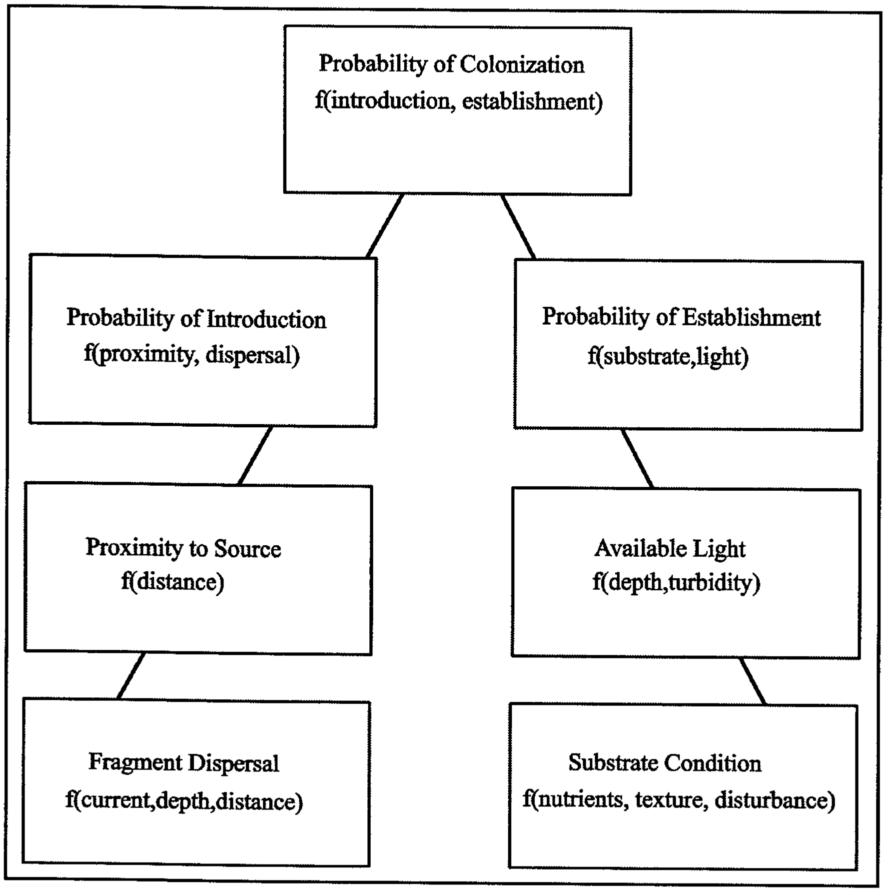

Figure 1. Concept flow diagram (introduction vs. establishment)

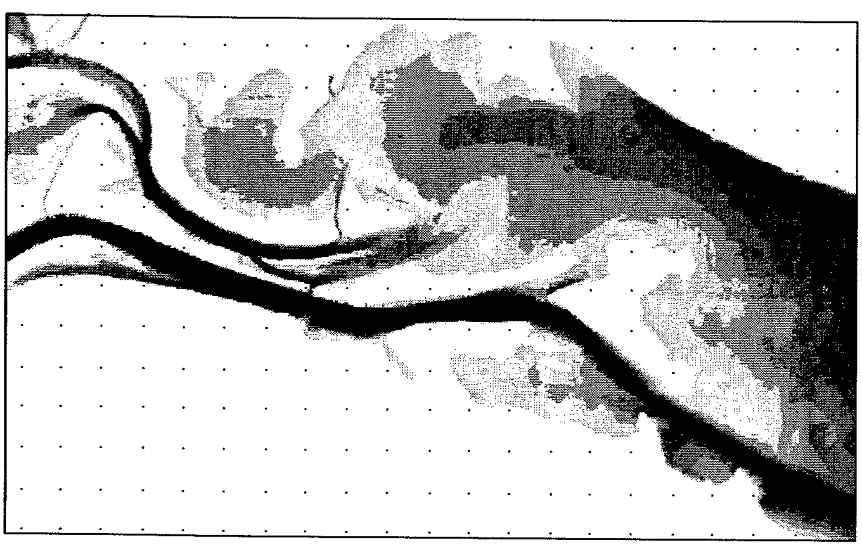

Figure 2. Pool 4 bathymetry

The spatial variable of proximity is a function of distance and a possible introduction source of the plants. This could be where a noxious plant has been deposited at a public boat ramp. The proximity distance is calculated as a least distance for the entire area without regard to water flow. This results in a probability map (Figure 4) showing that areas immediately close to the point of introduction as having a high probability versus areas of low probability (i.e, longer distances). Because the function of proximity involves only one variable, distance, it can also be visualized as a two-dimensional function (Figure 5).

The probability of introduction is a function of two previously described variables, proximity and fragment dispersal. This variable describes the probability of the proximity of introduction and dispersal routes of the plants or plant fragments (illustrated in Figure 6).

Probability of establishment of plant material

Substrate

The substrate variable is a function of substrate nutrients, substrate texture, substrate disturbance, and current (Figure 7). The composition and texture of bottom sediments affects the growth of rooted aquatic vegetation. Generally it has been shown that diminished growth occurs at low sediment density values and in sands at high sediment density values (Barko and Smart 1986). Growth is highly dependent on both texture and nutrients.

Water current is a more dominant factor than wind fetch in the case for Pool 4. At other sites, this might not be the case. A current speed of 50 cm/sec is currently used as a limiting condition for the establishment of the plants.

Light

Available light is a function of depth and water turbidity. Water turbidity was obtained from average daily measurements (May of 1995). The light intensity available for submerged aquatic plants is a function of the light intensity at the water surface and the log base of the negative extinction coefficient (May value was -2.89 m-1) at the bottom depth (see Equation 1). The result is shown in Figure 4, where the light intensity was set to unity and values range from 0.98 to 0.0.

$$I_z = I_0 e^{(-2.89z)} \qquad (1)$$

Light transmittance and attenuation are parameters that influence the establishment of aquatic plants (Barko, Adams, and Clasceri 1986). In Figure 8, Secci disk readings have been averaged for each month in Pool 4 and converted to a light extinction coefficient (Giesen, van Katwijk, and den Hartog 1990) to show light transmittance as a function of depth. Transmittance is shown as a percent of the available light that reaches the indicated depth needed by the plants. Each layer can be represented as monthly averages (Figure 9), where turbidity changes impact the probability of plant establishment.

The probability of establishment is derived using both available light and substrate condition. Figure 10 depicts the probability of establishment for Pool 4.

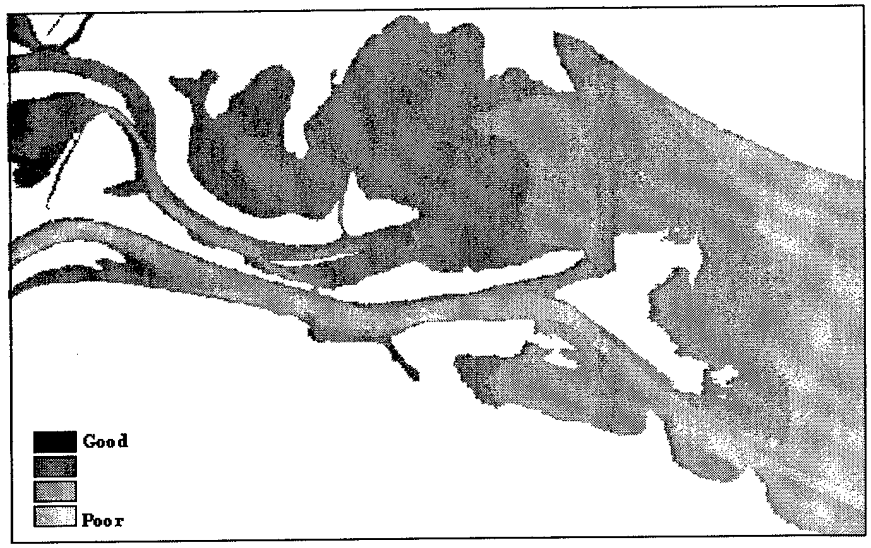

Figure 3. Plant fragment dispersal

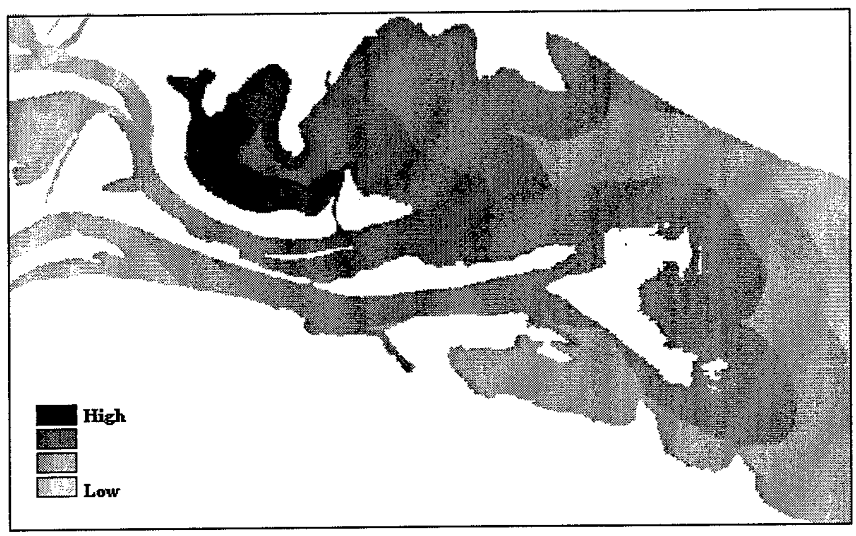

Figure 4. Proximity to the source of introduction

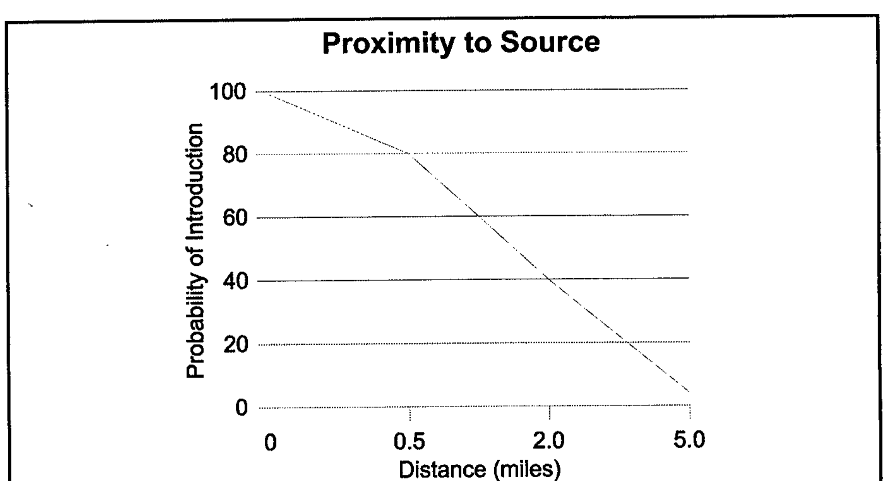

Figure 5. Theoretical probability of proximity to source of introduction

Figure 6. Probability of introduction as a function of dispersal and introduction

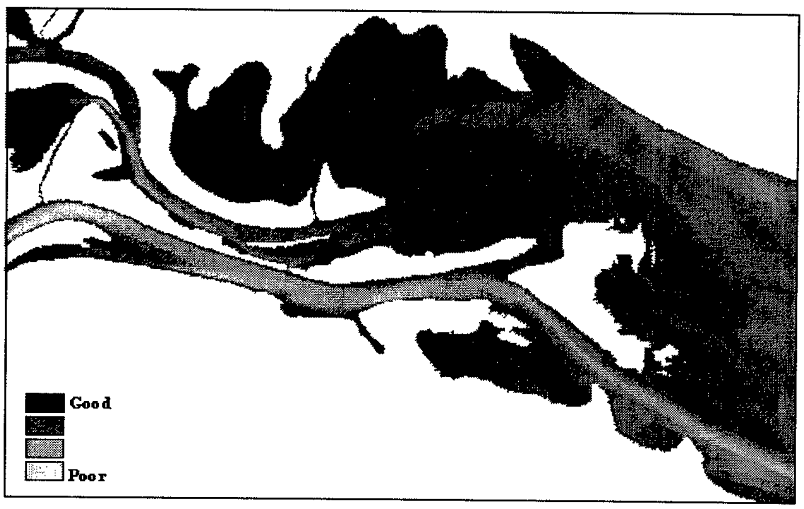

Figure 7. Substrate condition

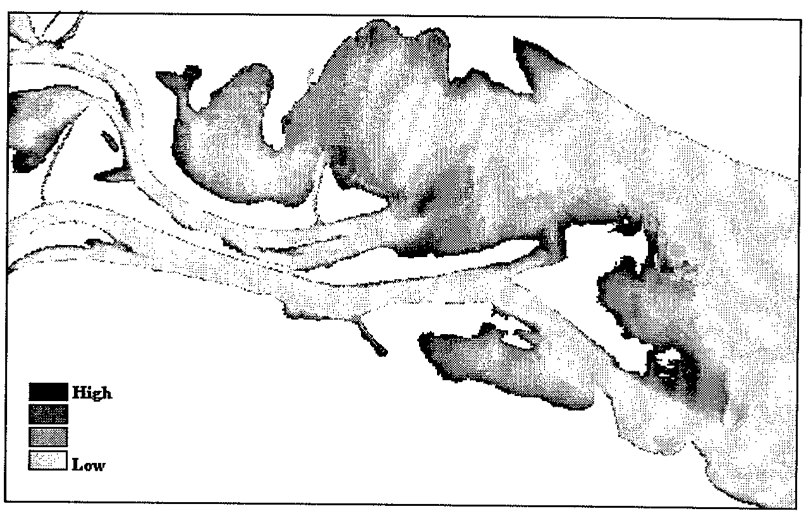

Figure 8. Available daily light average for May

Colonization of plant material

The conceptual colonization methodology integrates all of the previously described variables spatially. This is illustrated in Equation 2. In this equation, all the *P* variables are the variable probabilities and the *w* variables are weights of importance. The weights of importance can be derived from logistic multiple regression (Narumalani et al. 1997). The final result of this calculation gives the probability of aquatic plant colonization.

$$P_c = w_l P_l \cdot w_e P_e \cdot w_i P_i \cdot w_s P_s \cdot w_d P_d \qquad (2)$$

The probability of colonization for Pool 4 in the Upper Mississippi River is shown as Figure 11. This is based on **one** point of introduction of plant material as shown in Figure 4. This graphic shows that aquatic plant colonization is limited to the near shoreline and shallow-water areas of Pool 4, which is considered a reasonable assessment based on site geospatial data and aquatic plant research conducted to date.

Summary

The conceptual methodology for predicting the probability of colonization of aquatic plants has been described and is a function of several biophysical factors. This conceptual procedure was applied to Pool 4 on the Upper Mississippi River and probabilities of plant colonization were generated. These first-generation analytical procedures were considered realistic based on site conditions within Pool 4. The conceptual procedure is presently undergoing some

additional refinement and will be tested and evaluated to determine how well it depicts actual colonization conditions in different geographic regions and water body/site conditions.

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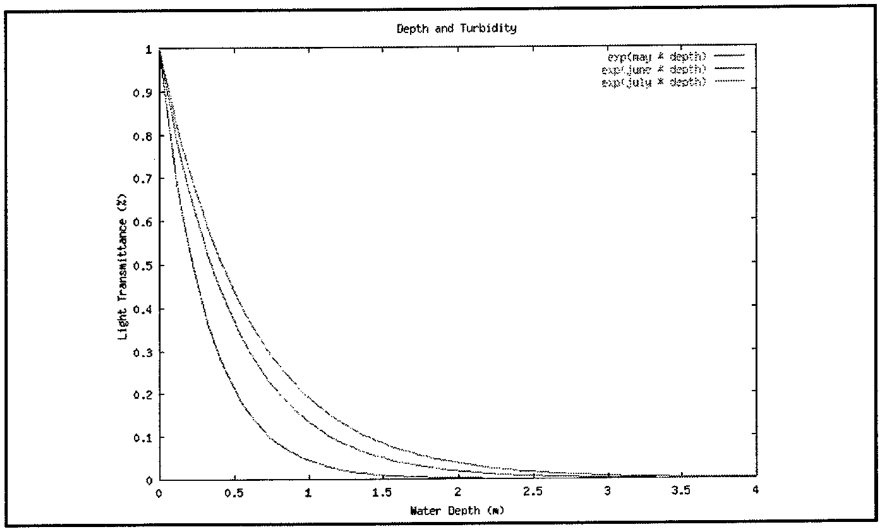

Figure 9. Light transmittance and water depth

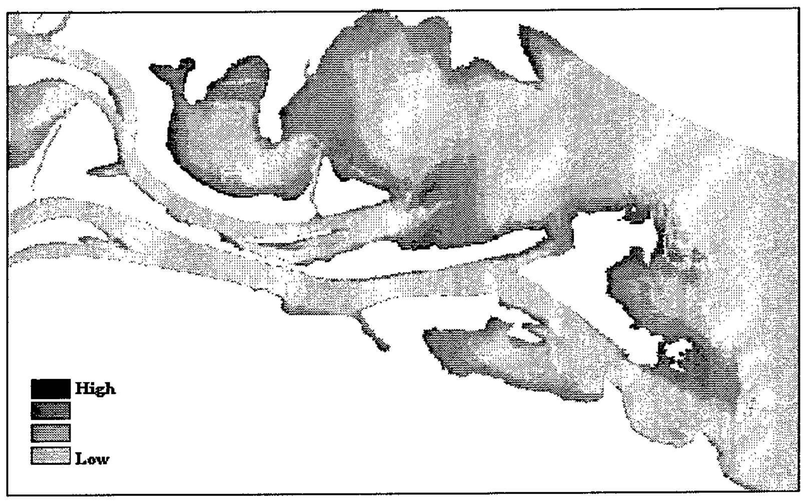

Figure 10. Probability of establishment, Pool 4

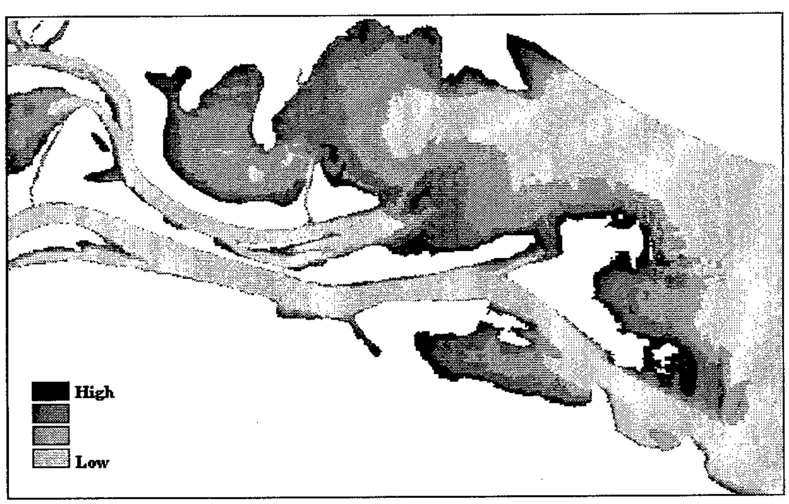

Figure 11. Probability of colonization for Pool 4

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